AD-A126 649

UNCLASSIFIED

AD-A126 649

Technical Report

distributed by

DEFENSE TECHNICAL INFORMATION CENTER

DTIC

Acquiring Information –
Imparting Knowledge

Defense Logistics Agency
Defense Technical Information Center
Cameron Station
Alexandria, Virginia 22304-6145

UNCLASSIFIED

NOTICE

We are pleased to supply this document in response to your request.

The acquisition of technical reports, notes, memorandums, etc., is an active, ongoing program at the **Defense Technical Information Center (DTIC)** that depends, in part, on the efforts and interest of users and contributors.

Therefore, if you know of the existence of any significant reports, etc., that are not in the **DTIC** collection, we would appreciate receiving copies or information related to their sources and availability.

The appropriate regulations are Department of Defense Directive 3200.12, DoD Scientific and Technical Information Program; Department of Defense Directive 5230.24, Distribution Statements on Technical Documents *(amended by Secretary of Defense Memorandum, 18 Mar 1984, subject: Control of Unclassified Technology with Military Application)*; American National Standard Institute *(ANSI)* Standard Z39.18, Scientific and Technical Reports: Organization, Preparation, and Production; Department of Defense 5200.1R, Information Security Program Regulation.

Our Acquisition Section, **DTIC-FDAB**, will assist in resolving any questions you may have. Telephone numbers of that office are:
(202) 274-6847, (202) 274-6874 or Autovon **284-6847, 284-6874**.

DO NOT RETURN THIS DOCUMENT TO DTIC

EACH ACTIVITY IS RESPONSIBLE FOR DESTRUCTION OF THIS DOCUMENT ACCORDING TO APPLICABLE REGULATIONS.

(12)

AD

AD-E400 993

AD A 126649

TECHNICAL REPORT ARLCD-TR-83016

MINIMUM NONPROPAGATION DISTANCES FOR M42/M46 GP GRENADE LOADING TOOLS

WILLIAM M. STIRRAT

MARCH 1983

US ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND
LARGE CALIBER
WEAPON SYSTEMS LABORATORY
DOVER, NEW JERSEY

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: Technical Report ARLCD-TR-83016	2. GOVT ACCESSION NO.: AD-A126 149
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): MINIMUM NONPROPAGATION DISTANCES FOR M42/M46 GP GRENADE LOADING TOOLS	5. TYPE OF REPORT & PERIOD COVERED: Final Dec 79 - Nov 81
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): William M. Stirrat	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: ARRADCOM, LCWSL Energetic Systems Process Div (DRDAR-LCM-SP) Dover, NJ 07801	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: MMT-5804288
11. CONTROLLING OFFICE NAME AND ADDRESS: ARRADCOM, TSD STINFO Div (DRDAR-TSS) Dover, NJ 07801	12. REPORT DATE: March 1983
	13. NUMBER OF PAGES: 55
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)	15. SECURITY CLASS. (of this report): Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

This program was accomplished as part of the U.S. Army's Manufacturing Methods and Technology program. The primary objective of this program is to develop, on a timely basis, manufacturing processes, techniques and equipment for use in production of Army materiel. Test coordination and basic data reduction (cont)

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Minimum nonpropagation distance	Composition A5
M42/M46 GP grenades	Grenade loading tools
155-mm M483 projectile	MMT - Ammunition
8-Inch M509 projectile	Load, assemble, pack facilities

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

As part of an Army-wide expansion and modernization program, the safe separation distance criteria to specifically support modernization concepts for the assembly of M42/M46 GP Grenades into various projectiles were studied. The test results from this program were used to establish safety criteria for new and existing explosives manufacturing facilities. A series of exploratory and confirmatory tests were conducted for each of the three loading tool configurations studied (two ring packs and a cluster tray).

(cont)

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

18. SUPPLEMENTARY NOTES (cont)

were accomplished by the ARRADCOM Resident Operations Office, National Space Technology Laboratories, NSTL Station, Mississippi. Both exploratory and confirmatory test phases were conducted by the Hazards Range Support Unit of Computer Science Corporation of NSTL.

20. ABSTRACT (cont)

The M483 ring pack, containing eight grenades, had a nonpropagation distance of 30 centimeters (12 inches) with a propagation probability of 6.98%.

The M509 ring pack, containing 15 grenades, had a nonpropagation distance of 45 centimeters (18 inches) with a propagation probability of 7.11%.

The cluster trays, each containing four rings of eight grenades, were found to have only a 6.25% propagation probability within the trays; therefore, zero spacing between trays has been safety approved.

ACKNOWLEDGMENTS

The author wishes to express his sincere appreciation to D. Kogar and R. Brack of the ARRADCOM Resident Operations Office, National Space Technology Laboratories, Mississippi, for the preparation of the detailed test plans and the coordination of the actual testing program; and to R. Amend, S. Fuentes, L. Mars, H. Stover and B. Templeton of the Hazards Range Support Unit, Computer Science Corporation, NSTL Station, Mississippi, for conducting both series of exploratory and confirmatory tests and collating the resulting data.

CONTENTS

TABLES

FIGURES

INTRODUCTION

Background

At the present time, an Army-wide modernization program is in the process of upgrading existing, and developing new, explosive manufacturing and Load-Assemble-Pack (LAP) facilities. This programmed effort will enable the U.S. Army to achieve increased production cost effectiveness with improved functional safety of the man/item relationship, as well as to be responsive to providing manufacturing facilities for future weaponry systems within the existing facilities. As an integral part of this program, the Energetic Systems Process Division, Large Caliber Weapon Systems Laboratory, ARRADCOM, Dover, New Jersey, is engaged in the continuous development of functionally responsive safety criteria as an activity entitled "Safety Engineering in Support of Ammunition Plants", which includes the establishment of safe separation (non-propagation) distance studies of munition end-items as well as bulk in-process explosive materials. The criteria, developed under the auspices of this program, will be utilized as part of the basis for the design of all explosive installations due for modernization, and will be available for reference purposes to privately-owned and operated (POPO) plants engaged in ordnance manufacturing operations.

The activities encompassed within this report will provide safety criteria data to specifically support facility modernization provisions in the overall LAP concept for the assembly of M42/M46 GP Grenades into both the 155mm M483 and the 8-Inch M509 HE Projectiles at various loading plants. Two-grenade loading tool concepts, an interim cluster tray (fig. 1) and grenade ring packs (figs. 2 and 3) were reviewed and a test program was then implemented to simulate the appropriate conveyor system test arrays.

Objective

The primary objective of this program is to establish and statistically confirm, through experimental evaluation, the safe non-propagative separation distance for various configurations of M42/M46 GP Grenades, contained within two types of loading tools, as they are transported on continuous feed conveyor systems for their final assembly into either 155mm M483 or 8-Inch M509 HE Projectiles. The data derived from this program will be utilized to establish criteria for unit spacing on conveyors, conveyor speeds and production rates for the manufacture of the aforementioned projectiles.

The overall program objective is to supplement and/or modify existing safety regulations and criteria pertaining to the safe spacing of ammunition and other energetic materials in order to assist explosive loading plants in their LAP facility layouts.

Criteria

This test program was implemented in order to determine the safe conveyor spacing for two-grenade transfer and loading tool concepts, to increase projectile loading efficiency and thus production rates, under simulated loading plant conditions. Said conveyor safe spacing is necessary to insure that the effects of a major unscheduled detonation of a munition on an assembly line will be limited to the immediate area or loading station, and not be propagated to either adjacent loading activities or the entire facility, causing catastrophic results. Therefore, the only acceptable criteria in the establishment of safe separation distances is the non-propagation of the initiated donor detonation to the acceptor units.

Note that all safe separation distances specified within this report are measured from nearest edge to nearest edge between the grenade loading tool donor and acceptor units.

TEST CONFIGURATION

M42/M46 GP Grenade Ring Packs

General

Testing of the two M42/M46 GP Grenade ring pack loading tools to establish and statistically confirm the minimum non-propagative distance between donor and acceptor units under simulated manufacturing line conditions was conducted under the auspices of the ARRADCOM Resident Operations Office at the National Space Technolgoy Laboratory's Hazard Range Tests Facility in Mississippi.

The actual test program consisted of two portions, each utilizing an exploratory phase and an ensuing confirmatory phase to statistically establish confidence in the resultant safe separation distances. The two program portions corresponding to the two-grenade ring pack loading tools are as follows:

1. 155mm M483 Ring Pack: Contains a complete projectile layer of grenades, consisting of eight, either M42 or M46 GP, Grenades. The grenades are arrayed in a circular pattern of seven, with the eighth grenade being in the center and the assembly being held in-place by a series of spacers, one keyed to the projectile body for alignment purpose. The whole grenade array is held together by a spring steel ring, 14.60 cm (5.75 in) in outside diameter and 12.70 cm (5.00 in) in inside diameter by 1.91 cm (0.75 in) thick (fig. 2).

2. 8-Inch M509 Ring Pack: Contains a complete layer of M42 GP Grenades (15 each), arrayed in a pattern similar to the M483 ring pack and also contained within a spring steel ring (fig. 3). However, this ring is 20.35 cm (8.00 in) in outside diameter and 17.42 cm (6.85 in) in inside diameter by 1.91 cm (0.75 in) thick.

Test Arrangements

Each test setup consisted of a donor and two-acceptor grenade ring packs arrayed in a straight line and raised off the ground to simulate the conveyor system's average height above the building's floor, as shown in figure 4. The center specimen served as the donor, while the ring packs at the extremities of the array served as the acceptor specimens, thus producing two-acceptor sets of test data results for each test donor detonated. During the exploratory test phase, the test separation distance between the donor and the acceptor ring packs was varied, not only from test to test, but also within single test firings. However, the donor-to-acceptor separation distance was always held constant during the confirmatory phase.

The test program portion for the 155mm M483 HE Projectile's grenade ring packs consisted of an exploratory and confirmatory test phase. The exploratory phase of this portion consisted of a test array of three ring packs, each containing eight M42 GP Grenades, arranged in a straight line, on a 2.54 by 30.05 cm (1.0 by 12.0 in) pine board to simulate the conveyor system. The complete test array was then supported by low density concrete blocks (one under each acceptor), approximately 45.7 cm (18.0 in) above the existing terrain in an attempt to fully simulate the LAP facility's conveyor system. During the exploratory phase, which consisted of 17 test detonations, the separation distances, measured edge to edge, ranged from 15.0 to 61 cm (6.0 to 24.0 in). The confirmatory test phase on the M483 ring packs consisted of a series of 26 tests, utilizing the exact same test array as in the exploratory phase; however, the separation distances were held constant in order to amass the necessary statistical data. Figure 5 is a pre-test view of the M483 ring pack array. In all cases, the left and right acceptors were color-coded for ease of post-test identification, and all three test units always had a witness plate for post-test analysis of donor detonation and subsequent (if any) propagations. Also, as noted in figure 5, sandbags were utilized behind the acceptors to prevent grenade scattering and aid in post-test analysis and clean-up.

The test program for the 8-Inch M509 HE Projectile's grenade ring packs was basically the same as that for the M483 ring packs. During the exploratory phase, which consisted of seven test detonations, the separation distances ranged from 30.0 to 45.0 cm (12.0 to 28.0 in). The confirmatory test phase consisted of 25 tests utilizing the exact same distance in all tests. Figure 6 is a pre-test view of the M509 ring pack array. Again, the only variation from the M483 ring pack array is larger witness plates to fully accommodate the larger ring of grenades.

M42/M46 GP Grenade Cluster Tray

General

Testing of the M42/M46 GP Grenade cluster trays to establish and statistically confirm the minimum non-propagative distance between donor and acceptor units under simulated manufacturing line conditions was also conducted under the auspices of the ARRADCOM Resident Operations Office at the National Space Technology Laboratory's Hazard Range Test Facility in Mississippi.

The test program initially was to consist of two portions, each utilizing an exploratory and confirmatory phase. The portions were to correspond to the two-grenade cluster tray arrays proposed for use on the facility's conveyor systems. They were:

1. A single cluster tray containing 32 each M42 GP Grenades arranged in four rings of eight grenades each. The cluster tray (fig. 1) is 30.95 by 40.50 cm (12.19 by 15.94 in) and is 3.00 cm (1.18 in) thick, and consists of four circular cavities to hold the grenade layers and two rectangular cavities for spare inserts or other loading components. The tray is vacuum-molded from a general purpose ABS plastic material.

2. A double cluster tray, consisting of two trays locked together by a steel pin, and containing 64 each M42 GP Grenades arranged in eight rings (four per tray) of eight grenades each.

Test Arrangements

Each test setup, both single and dual cluster tray, was to consist of a donor and two acceptor units arrayed in a straight line and raised off the ground to simulate the conveyor system's average height above the building's floor, as shown in figures 7 and 8, respectively. The center specimen in each case served as the donor, while the cluster trays at the extremities of the array served as the acceptor specimens.

During the exploratory test phase, which included five single and two dual tray tests, extreme difficulties were encountered in achieving full donor high order detonations. Therefore, the test plan was modified as a field expedient to the testing of propagation potential between grenade layers in a single tray. Since the trays would be touching and the closest grenade layer to the donor layer would be in an adjoining tray, the test array in figure 9 was utilized. This test array consisted of two cluster trays joined by the connector pin and containing six clusters, each containing eight grenades. After conducting three exploratory tests utilizing this configuration, a total of 64 confirmatory tests were run. The excessively large number of confirmatory tests were due to two reasons:

1. The non-uniformity of the test array only yielded one data point per test and

2. A few partial high order donor detonations necessitated a number of retests.

Test Specimens

Every test portion of this program, both ring pack and cluster tray, utilized the same basic test specimen, the M42 General Purpose (GP) Grenade. Since it was felt that the controlled fragmentation of the M42 GP Grenade was a more severe test than the uncontrolled fragmentation of the M46 Grenade, only M42 Grenades were utilized. Also, since the M223 Fuze was held in an out-of-line condition by two loading safeties, a roll pin and a spring clip, and had previously passed its out-of-line non-functioning safety tests, only unfuzed grenades were utilized by the test program in order to provide a safer post test clean-up atmosphere. The M42 and M46 GP Grenades' basic dimensions are 6.25 cm (2.46 in) in length with a maximum diameter of 3.89 cm (1.53 in) and contain a minimum of 30 grams (0.07 pound) of A5 Composition in a shaped charge configuration.

Method of Initiation

M483/M509 Ring Packs

The donor specimen in both ring pack test arrays was primed with two J2 electric blasting caps directly aligned with the unfuzed grenades' lead cup assemblies. In all cases, a steel witness plate, 1.27 cm (0.50 in) thick, was placed below the donor to provide a record of a high order detonation. The M483 donor ring pack (fig. 10) utilizes the two blasting caps in diametrically opposite grenades in the ring of seven; while the M509 donor ring pack (fig. 11) utilizes the two blasting caps in diametrically opposite grenades in the inner ring of five. In both cases, all tests resulted in a complete donor high order detonation with all shape charges penetrating the witness plate (fig. 12).

M483 Cluster Trays

The donor specimen in both the single and dual cluster tray test arrays (figs. 13 and 14, respectively) initially had two J2 or M6 electric blasting caps directly aligned with the unfuzed grenades' lead cup assemblies on each grenade layer. Thus, the single-tray array utilized eight blasting caps for the four layers and the dual-tray array utilized 16 blasting caps for the eight layers. However, since the donor witness plates, in both cases, sometimes gave evidence of only partial donor functioning as shown in figure 15 (note incomplete penetration circles), the ignition system was revised to three blasting caps per grenade layer. This array utilized two of the blasting caps in diametrically opposite grenades in the outer rang of seven and the third blasting cap located over the center or eighth grenade. Due to the inherent variations in blasting cap functioning time, the ignition system did not initiate the whole donor specimen to a fully high order detonation; therefore, the test plan was revised. The final cluster tray test array, as shown in figure 9, utilized the three blasting cap ignition system on a single grenade layer, still with mixed results (11 partial donor detonations out of 67 firings).

TEST RESULTS

M42/M46 GP Grenade Ring Packs

As previously stated, the Safe Separation Distance Study Program for the grenade pack consists of two separate test portions, one with rings of eight grenades for M483 projectiles and the other with rings of 15 grenades for M509 projectiles. Also, each test portion was further subdivided into two test sections; namely, exploratory and confirmatory tests. The results of the various tests are discussed below:

M483 Projectile Ring Pack

A total of 17 exploratory tests (test nos. 1 to 17 inclusive of table 1) were conducted utilizing separation distances (ring pack edge to edge) from 15.0 to 51.0 cm (6.0 to 24.0 in) with high order propagations of the donor detonations occurring up to the 23.0-cm (9.0-in) spacing. Figures 16, 17 and 18 illustrate representative post-test results. Figure 16 is a general view of a test wherein no propagation of the donor detonation occurred (note the whole acceptor grenades in the foreground). Figure 17 shows a high order propagation to the right, on the nearest acceptor [note the penetrations of both the donor (center) and right acceptor witness plates]. Figure 18 demonstrates a typical post-test close-up of a non-propagating test array at the 30-cm (12-in) spacing (note fully penetrated donor witness plate and relatively undamaged acceptor grenades).

The confirmatory test phase consisted of 26 test detonations (test nos. 18 to 43 inclusive of table 1), thus yielding 52 valid data points. All tests were conducted at the 30-cm (12-in) spacing between donor and acceptor ring packs and while light-to-medium damage was encountered on some acceptor grenades, there was, in no case, any propagation of a donor detonation.

M509 Projectile Ring Pack

A total of eight exploratory tests (test nos. 1 to 8 inclusive of table 2) were conducted utilizing separation distances (ring pack edge to edge) from 30.0 to 45.0 cm (12.0 to 18.0 in) with no high order propagation occurring at any spacing. However, the amount of acceptor damage at the 30-cm (12-in) spacing would have led to an eventual propagation. Figure 19 is a general view of a test where there was no detonation propagation and where both acceptors remained intact. Figures 20 shows a post-test close-up of a similar test array.

The confirmatory test phase consisted of 25 test detonations involving 50 acceptor specimens (test nos. 8 to 32 inclusive of table 3). All tests were conducted at the 45-cm (18-in) spacing between donor and acceptor ring packs, with little or no damage to any of the acceptor specimens.

M483 Cluster Trays

As formerly mentioned, the Non-Propagation Study Program for the M42 Grenade cluster trays for the M483 Projectile originally was to consist of two separate test portions, single- and dual-tray tests. However, due to ignition system problems with the simultaneous ignition of between 8 to 24 blasting caps, donor high order detonation reliability was highly questionable; therefore, the test plan was revised to determine the propagation between grenade layers within a dual cluster tray.

The initial testing of both single and dual cluster trays consisted of seven test detonations, five for single and two for dual cluster tray arrays (tests nos. 1 to 7 inclusive of table 3). Separation distances in both cases ranged from touching to 122.0 cm (48.0 in) and 205 cm (84.0 in) for single and dual arrays, respectively. While there was no detonation propagation in any of the tests, the aforementioned problem of reliable donor high order detonation made the results suspect.

After a review of the single and dual tray results, the test plan was modified to determine propagation between the grenade rings of a dual tray array (fig. 9). A series of three exploratory tests (test nos. 8, 9 and 10 of table 3) followed by 64 confirmatory tests (table 4) were conducted on this dual cluster tray configuration; however, due to donor initiator malfunctions, only 56 tests were considered to be valid data points. In all the tests conducted, there were no high order propagations occurring between the grenade rings within the dual cluster tray array. Figure 21 is a post-test view of the final test array results (note that while grenades may be damaged and/or ruptured, none functioned).

Analysis of Test Results

Variations in manufacturing tolerances, materials, wear, etc., required that statistical reasoning be employed in the interpretation of the various sets of confirmatory test data. The actual probability of the continuous propagation of an unexpected explosive incident on a LAP facility ammunition production line is a function of a number of propagation occurrences in a particular test phase as related to the total number of test detonations conducted (see appendix for statistical theory).

For the M42 GP Grenade ring pack of the 155mm M483 HE Projectile (eight grenades each), there was a total of 52 observations recorded at the 30-cm (12-in) safe separation distance, resulting in an upper limit of 6.98 percent probability of propagation of an explosive incident at the 95 percent confidence level. The grenade ring pack for the 8-Inch M509 HE Projectile (15 grenades) had a total of 50 confirmation data points recorded at a 45-cm (18-in) safe separation distance, resulting in an upper limit of 7.11 percent probability of propagation of an explosive incident at the 95 percent confidence level.

For the M42 GP Grenade cluster tray of the 155mm M483 HE Projectile, there was a total of 56 test data points for the dual tray configuration (zero spacing between trays), resulting in an upper limit of 6.25 percent probability of an explosive incident in one ring of eight grenades, propagating to any of the adjacent grenade rings at the 95 percent confidence level.

These values are equivalent to stating that in a large number of tests, 95 out of 100 times, the probability of an unexpected explosive incident propagating to a catastrophic event will be less than, or equal to, the stated values above. These values indicate the quality of the test results and the reliance that can be placed upon the conclusions drawn from the data.

CONCLUSIONS

It may be concluded from the test results of the M483 Ring Pack that the safe separation distance is 30 cm (12 in) between rings containing eight M42 GP Grenades, with the probablility of the propagation of an explosive incident being 6.98 percent at the 95 percent confidence level.

The safe separation distance between M509 ring packs containing fifteen each M42 GP Grenades is 45 cm (18 in) with the probability of the propagation of an explosive incident being 7.11 percent at the 95 percent confidence level.

Due to ignition difficulties, it was concluded that it was highly unlikely that either a single or a dual cluster tray containing 32 and 64 M42 GP Grenades, respectively, would simultaneously function to a high order detonation. Therefore, testing was revised to determine the propagation potential between adjacent rings of eight grenades within a dual cluster tray array. Thus, with zero spacing between the cluster trays, the probability of the propagation of an explosive incident between grenade rings is 6.25 percent at the 95 percent confidence level.

Table 1. M42 GP Grenade Ring Pack (8) for 155mm M483 HE Projectile

Test No.		Distance cm	(in)	Remarks
1	L	30	(12)	NDP[a] no damage[b]
	R	61	(24)	NDP, no damage
2	L	61	(24)	NDP, no damage
	R	30	(12)	NDP, light damage[c]
3	L	30	(12)	NDP, light damage
	R	15	(6)	NDP, medium damage[d]
4	L	15	(6)	NDP, heavy damage[e]
	R	15	(6)	NDP, heavy damage
5	L	23	(9)	NDP, light damage
	R	23	(9)	NDP, medium damage
6	L	23	(9)	NDP, light damage
	R	23	(9)	NDP, light damage
7	L	23	(9)	NDP, medium damage
	R	23	(9)	NDP, light damage
8	L	23	(9)	NDP, medium damage
	R	23	(9)	NDP, light damage
9	L	23	(9)	NDP, light damage
	R	23	(9)	NDP, light damage
10	L	23	(9)	NDP, light damage
	R	23	(9)	NDP, light damage
11	L	23	(9)	NDP, medium damage
	R	23	(9)	NDP, medium damage
12	L	23	(9)	NDP, light damage
	R	23	(9)	NDP, light damage
13	L	23	(9)	NDP, light damage
	R	23	(9)	NDP, light damage
14	L	23	(9)	NDP, medium damage
	R	23	(9)	NDP, medium damage
15	L	23	(9)	NDP, medium damage
	R	23	(9)	NDP, medium damage
16	L	23	(9)	NDP, light damage
	R	23	(9)	NDP, medium damage
17	L	23	(9)	NDP, medium damage
	R	23	(9)	HOD[f] all 8 grenades
18	L	30	(12)	NDP, light damage
	R	30	(12)	NDP, light damage
19	L	30	(12)	NDP, light damage
	R	30	(12)	NDP, light damage
20	L	30	(12)	NDP, light damage
	R	30	(12)	NDP, light damage
21	L	30	(12)	NDP, light damage
	R	30	(12)	NDP, light damage
22	L	30	(12)	NDP, light damage
	R	30	(12)	NDP, light damage
23	L	30	(12)	NDP, no damage
	R	30	(12)	NDP, light damage
24	L	30	(12)	NDP, light damage
	R	30	(12)	NDP, no damage
25	L	30	(12)	NDP, light damage
	R	30	(12)	NDP, light damage
26	L	30	(12)	NDP, light damage
	R	30	(12)	NDP, light damage
27	L	30	(12)	NDP, medium damage
	R	30	(12)	NDP, light damage
28	L	30	(12)	NDP, light damage
	R	30	(12)	NDP, medium damage
29	L	30	(12)	NDP, medium damage
	R	30	(12)	NDP, light damage
30	L	30	(12)	NDP, no damage
	R	30	(12)	NDP, light damage

Table 1. (cont)

Test No.		Distance cm	(in)	Remarks	Test No.		Distance cm	(in)	Remarks
31	L	30	(12)	NDP, no damage	38	L	30	(12)	NDP, light damage
	R	30	(12)	NDP, light damage		R	30	(12)	NDP, no damage
32	L	30	(12)	NDP, light damage	39	L	30	(12)	NDP, light damage
	R	30	(12)	NDP, no damage		R	30	(12)	NDP, no damage
33	L	30	(12)	NDP, light damage	40	L	30	(12)	NDP, light damage
	R	30	(12)	NDP, light damage		R	30	(12)	NDP, medium damage
34	L	30	(12)	NDP, light damage	41	L	30	(12)	NDP, medium damage
	R	30	(12)	NDP, light damage		R	30	(12)	NDP, medium damage
35	L	30	(12)	NDP, light damage	42	L	30	(12)	NDP, no damage
	R	30	(12)	NDP, no damage		R	30	(12)	NDP, light damage
36	L	30	(12)	NDP, light damage	43	L	30	(12)	NDP, light damage
	R	30	(12)	NDP, no damage		R	30	(12)	NDP, no damage
37	L	30	(12)	NDP, light damage					
	R	30	(12)	NDP, no damage					

---

[a] NDP - No Detonation Propagation.

[b] No damage - All grenades and housing ring fully reusable.

[c] Light damage - Minor fragment impacts on grenades and housing ring.

[d] Medium damage - Few grenades destroyed, many penetrations of grenades and housing ring.

[e] Heavy damage - Most or all grenades destroyed or ruptured, housing ring broken or severely damaged.

[f] HOD - High Order Detonation.

Table 2. M42 GP Grenade Ring Pack (15) for 8-Inch M509 HE Projectile

Test No.		Distance cm	(in)	Remarks
1	L	30	(12)	NDP[a], medium damage[b]
	R	30	(12)	NDP, heavy damage[c]
2	L	30	(12)	NDP, light damage[d]
	R	30	(12)	NDP, light damage
3	L	30	(12)	NDP, medium damage
	R	30	(12)	NDP, heavy damage
4	L	30	(12)	NDP, heavy damage
	R	30	(12)	NDP, heavy damage
5	L	30	(12)	NDP, heavy damage
	R	30	(12)	NDP, medium damage
6	L	30	(12)	NDP, heavy damage
	R	30	(12)	NDP, medium damage
7	L	30	(12)	NDP, medium damage
	R	30	(12)	NDP, heavy damage
8	L	45	(18)	NDP, medium damage
	R	45	(18)	NDP, medium damage
9	L	45	(18)	NDP, light damage
	R	45	(18)	NDP, light damage
10	L	45	(18)	NDP, no damage
	R	45	(18)	NDP, no damage
11	L	45	(18)	NDP, no damage
	R	45	(18)	NDP, no damage
12	L	45	(18)	NDP, light damage
	R	45	(18)	NDP, no damage
13	L	45	(18)	NDP, no damage
	R	45	(18)	NDP, light damage
14	L	45	(18)	NDP, light damage
	R	45	(18)	NDP, no damage
15	L	45	(18)	NDP, no damage
	R	45	(18)	NDP, no damage
16	L	45	(18)	NDP, no damage
	R	45	(18)	NDP, light damage
17	L	45	(18)	NDP, no damage
	R	45	(18)	NDP, no damage
18	L	45	(18)	NDP, no damage
	R	45	(18)	NDP, no damage
19	L	45	(18)	NDP, light damage
	R	45	(18)	NDP, no damage
20	L	45	(18)	NDP, no damage
	R	45	(18)	NDP, light damage
21	L	45	(18)	NDP, no damage
	R	45	(18)	NDP, no damage
22	L	45	(18)	NDP, light damage
	R	45	(18)	NDP, no damage
23	L	45	(18)	NDP, no damage
	R	45	(18)	NDP, light damage
24	L	45	(18)	NDP, light damage
	R	45	(18)	NDP, no damage
25	L	45	(18)	NDP, light damage
	R	45	(18)	NDP, no damage
26	L	45	(18)	NDP, light damage
	R	45	(18)	NDP, light damage
27	L	45	(18)	NDP, no damage
	R	45	(18)	NDP, no damage
28	L	45	(18)	NDP, no damage
	R	45	(18)	NDP, no damage
29	L	45	(18)	NDP, medium damage
	R	45	(18)	NDP, no damage
30	L	45	(18)	NDP, no damage
	R	45	(18)	NDP, no damage

Table 2. (cont)

Test No.		Distance cm	(in)	Remarks	Test No.		Distance cm	(in)	Remarks
31	L	45	(18)	NDP, light damage	32	L	45	(18)	NDP, no damage
	R	45	(18)	NDP, light damage		R	45	(18)	NDP, light damage

---

[a] NDP - No Detonation Propagation.

[b] Medium damage - Few grenades destroyed, many penetrations of grenades and housing ring.

[c] Heavy damage - Most or all grenades destroyed or ruptured, housing ring broken or severely deformed.

[d] Light damage - Minor fragment impacts on grenades and housing ring.

Table 3. M42 GP Grenade Cluster Tray - Exploratory Phase

Test No.	Tray Array	Distance cm	(in)	Remarks
1L	Single	92.0	(36.0)	NDP*, nearest clusters scattered
R	(fig. 2)	122.0	(48.0)	NDP, one grenade damaged, nearest clusters scattered
2L	Single	30.0	(12.0)	NDP, tore up tray, scattered all clusters
R		61.0	(24.0)	NDP, tore up tray, scattered all clusters
3L	Single	Touching		NDP, 9 grenades damaged, all others scattered
R		15.0	(6.0)	NDP, 6 grenades damaged, all others scattered
4L	Dual	151.0	(60.0)	NDP, trays intact
R	(fig. 3)	205.0	(84.0)	NDP, trays intact
5L	Dual	92.0	(36.0)	Invalid test, with 3 grenades primed per grenade circle, donor did not fully detonate
R		Touching		
6L	Single	Touching		NDP, 16 grenades damaged, 5 missing
R		Touching		NDP, 16 grenades damaged, 2 missing
7L	Single	Touching		Invalid test, with 3 grenades primed per grenade circle, donor did not fully detonate
R		Touching		
8	Touching (fig. 4)	NA		NDP, 2 grenades destroyed, 4 damaged and 34 undamaged
9	Touching	NA		NDP, 4 grenades damaged and 36 undamaged
10	Touching	NA		Invalid test, with 3 grenades primed in donor circle, donor did not fully detonate

* NDP - No Detonation Propagation

Table 4. M42 GP Grenade Cluster Tray - Confirmatory Phase

Test No.	Donor No. Det.	Acceptor #1	Acceptor #2	Acceptor #3	Acceptor #4	Acceptor #5
		X,Y	X,Y	X,Y	X,Y	X,Y
1	8	NDP*, 0,5	NDP, 0,6	NDP, 0,1	NDP, 0,0	NDP, 0,0
2	8	NDP, 1,1	NDP, 1,0	NDP, 1,2	NDP, 0,2	NDP, 1.0
3	8	NDP, 1,0	NDP, 1,0	NDP, 1,1	NDP, 0,0	NDP, 0,1
4	8	NDP, 1,1	NDP, 1,0	NDP, 0,2	NDP, 0,0	NDP, 0,1
5	8	NDP, 3,0	NDP, 0,0	NDP, 0,2	NDP, 1,0	NDP, 0,1
6	2	Invalid test, donor did not fully detonate.				
7	8	NDP, 0,3	NDP, 0,3	NDP, 0,4	NDP, 0,3	NDP, 0,1
8	8	NDP, 1,1	NDP, 0,2	NDP, 0,5	NDP, 0,5	NDP, 0,1
9	8	NPD, 0,1	NDP, 0,0	NDP, 0,4	NDP, 0,3	NDP, 0,1
10	8	NDP, 2,1	NDP, 0,2	NDP, 2,0	NDP, 0,2	NDP, 2,0
11	8	NDP, 1,2	NDP, 0,0	NDP, 0,0	NDP, 0,1	NDP, 0,0
12	8	NDP, 3,0	NDP, 0,2	NDP, 4,0	NDP, 0,3	NDP, 0,3
13	8	NDP, 2,0	NDP, 0,2	NDP, 2,0	NDP, 0,2	NDP, 0,2
14	8	NDP, 3,0	NDP, 1,1	NDP, 2,0	NDP, 2.0	NDP, 1,2
15	8	NDP, 2,0	NDP, 0,2	NDP, 2,1	NDP, 0,3	NDP, 0,2
16	8	NDP, 2,1	NDP, 2,0	NDP, 3,0	NDP, 0,2	NDP, 0,2
17	8	NDP, 3,0	NDP, 0[illegible]	NDP, 3,1	NDP, 0,3	NDP, 2,1

Table 4. (cont)

Test No.	Donor No. Det.	Acceptor #1	Acceptor #2	Acceptor #3	Acceptor #4	Acceptor #5
		X,Y	X,Y	X,Y	X,Y	X,Y
18	8	NDP, 2,2	NDP, 0,3	NDP, 0,3	NDP, 0,4	NDP, 0,3
19	8	NDP, 2,2	NDP, 0,3	NDP, 0,3	NDP, 0,2	NDP, 0,3
20	8	NDP, 1,1	NDP, 1,3	NDP, 1,2	NDP, 0,4	NDP, 0,2
21	8	NDP, 2,1	NDP, 0,4	NDP, 1,2	NDP, 0,4	NDP, 0,2
22	8	NDP, 2,1	NDP, 0,4	NDP, 1,2	NDP, 0,3	NDP, 0,5
23	8	NDP, 3,0	NDP, 0,3	NDP, 2,1	NDP, 0,3	NDP, 0,3
24	8	NDP, 4,0	NDP, 0,4	NDP, 2,0	NDP, 0,2	NDP, 0,3
25	8	NDP, 0,2	NDP, 0,2	NDP, 1,1	NDP, 0,2	NDP, 0,1
26	1	Invalid test, donor did not fully detonate.				
27	8	NPD, 3,0	NDP, 1,1	NDP, 2,1	NDP, 1,1	NDP, 0,0
28	2	Invalid test, donor did not fully detonate.				
29	8	NDP, 2,2	NDP, 0,2	NDP, 1,2	NDP, 0,3	NDP, -,-
30	8	NDP, 1,2	NDP, 1,2	NDP, 1,2	NDP, 0,1	NDP, 0,2
31	8	NDP, 4,0	NDP, 0,2	NDP, 0,3	NDP, 1,2	NDP, 0,3
32	1	Invalid test, donor did not fully detonate.				
33	8	NDP, 2,2	NDP, 0,2	NDP, 0,3	NDP, 0,2	NDP, 0,1
34	8	NDP, 3,0	NDP, 0,3	NDP, 3,1	NDP, 0,2	NDP, 0,3

Table 4. (cont)

Test No.	Donor No. Det.	Acceptor #1	Acceptor #2	Acceptor #3	Acceptor #4	Acceptor #5
		X,Y	X,Y	X,Y	X,Y	X,Y
35	8	NDP, 2,1	NDP, 0,3	NDP, 2,1	NDP, 0,3	NDP, 0,1
36	8	NDP, 2,0	NDP, 1,2	NDP, 0,3	NDP, 0,2	NDP, 0,3
37	8	NDP, 1,2	NDP, 0,3	NDP, 3,0	NDP, 0,3	NDP, 1,2
38	8	NDP, 3,0	NDP, 0,2	NDP, 2,2	NDP, 0,2	NDP, 0,3
39	2	Invalid test, donor did not fully detonate.				
40	8	NDP, 1,2	NDP, 0,4	NDP, 1,2	NDP, 0,3	NDP, 0,3
41	8	NDP, 2,0	NDP, 0,3	NDP, 2,0	NDP, 0,2	NDP, 0,1
42	8	NDP, 1,1	NDP, 0,3	NDP, 2,2	NDP, 0,2	NDP, 1,2
43	8	NDP, 1,1	NDP, 1,2	NDP, 1,2	NDP, 0,3	NDP, 0,3
44	8	NDP, 2,1	NDP, 0,5	NDP, 0,4	NDP, 1,3	NDP, 0,2
45	8	NPD, 1,3	NDP, 0,3	NDP, 0,2	NDP, 0,3	NDP, 0,4
46	8	NDP, 4,0	NDP, 0,3	NDP, 0,3	NDP, 0,2	NDP, 0,1
47	3	Invalid test, donor did not fully detonate.				
48	8	NDP, 2,1	NDP, 1,1	NDP, 0,3	NDP, 1,2	NDP, 0,2
49	8	NDP, 2,1	NDP, 1,2	NDP, 0,4	NDP, 0,2	NDP, 0,2
50	8	NDP, 1,2	NDP, 0,3	NDP, 2,0	NDP, 1,1	NDP, 0,2
51	8	NDP, 3,0	NDP, 0,2	NDP, 3,0	NDP, 0,2	NDP, 1,2

Table 4. (cont)

Test No.	Donor No. Det.	Acceptor #1 X,Y	Acceptor #2 X,Y	Acceptor #3 X,Y	Acceptor #4 X,Y	Acceptor #5 X,Y
52	1	Invalid test, donor did not fully detonate.			NDP, 0,2	NDP, 0,3
53	8	NDP, 3,0	NDP, 0,2	NDP, 1,2	NDP, 0,3	NDP, 0,3
54	8	NDP, 4,0	NDP, 0,4	NDP, 0,5	NDP, 0,3	NDP, 1,3
55	8	NDP, 3,0	NDP, 0,2	NDP, 2,2		
56	1	Invalid test, donor did not fully detonate.				
57	8	NDP, 4,0	NDP, 0,4	NDP, 2,2	NDP, 0,2	NDP, 1,2
58	8	NDP, 2.2	NDP, 0,3	NDF, 1,2	NDP, 0,3	NDP, 0,1
59	1	Invalid test, donor did not fully detonate.				
60	8	NDP, 2,2	NDP, 2,1	NDP, 2,0	NDP, 0,3	NDP, 0,3
61	1	Invalid test, donor did not fully detonate.				
62	8	NDP, 2,2	NDP, 0,4	NDP, 1,3	NDP, 0,4	NDP, 3,5
63	8	NPD, 0,4	NDP, 0,3	NDP, 3,0	NDP, 0,2	NDP, 2,4
64	8	NDP, 3,1	NDP, 0,4	NDP, 0,2	NDP, 0,3	NDP, 3,4

* NDP - No Detonation Propagation

X - Number of grenades ruptured
Y - Number of grenades with hit marks

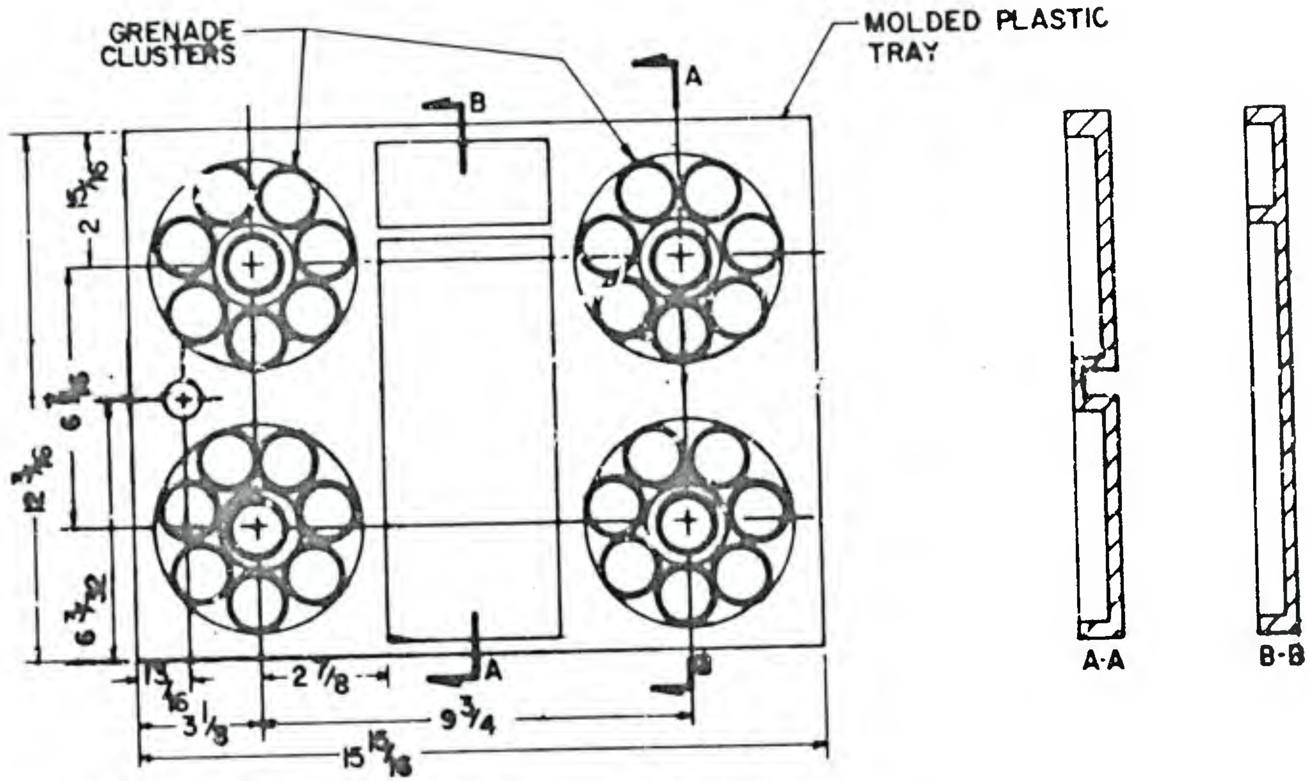

FIGURE 1. M42/M46 Grenade cluster tray

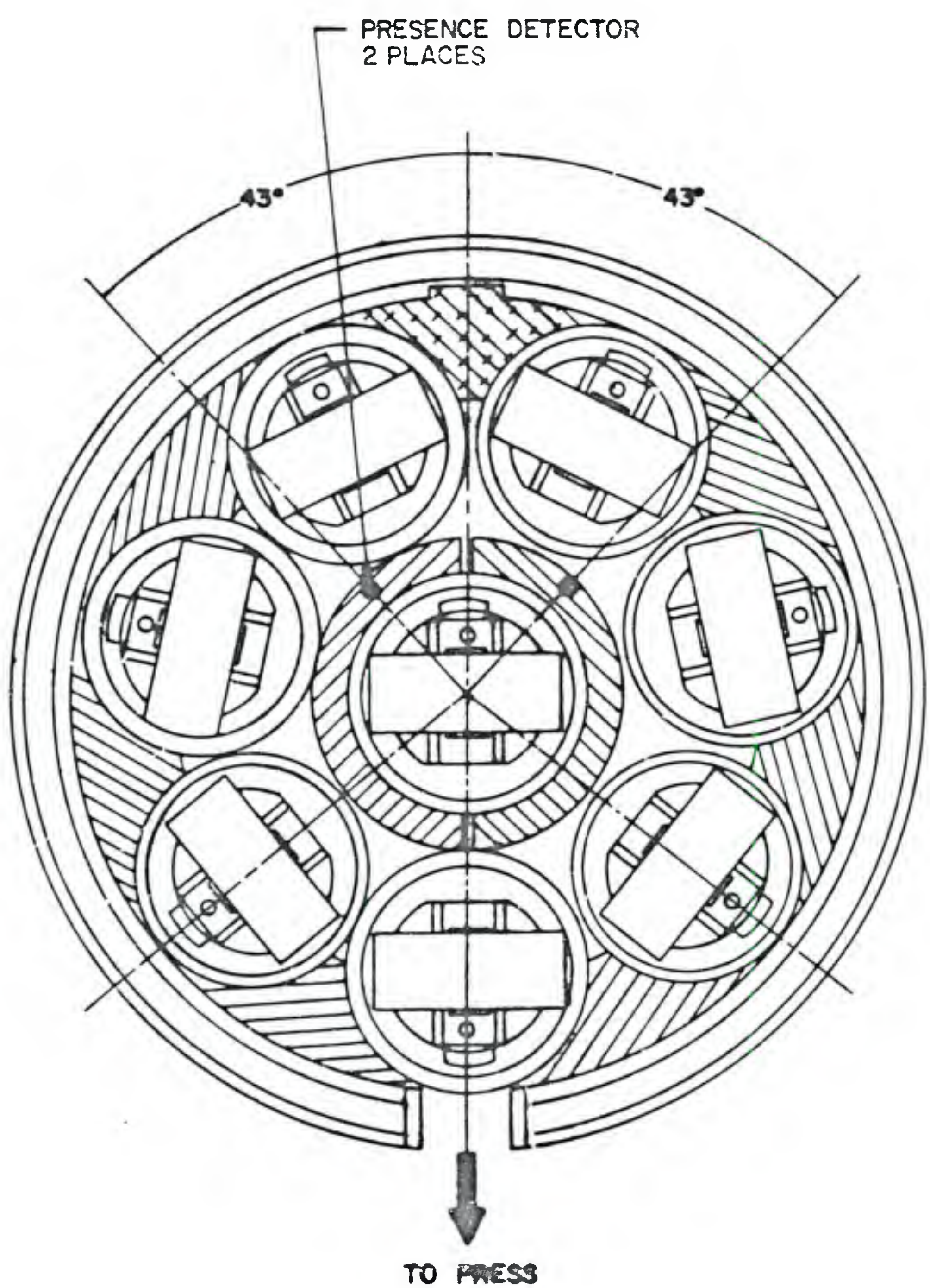

Figure 2. 155MM M483 ring pack configuration

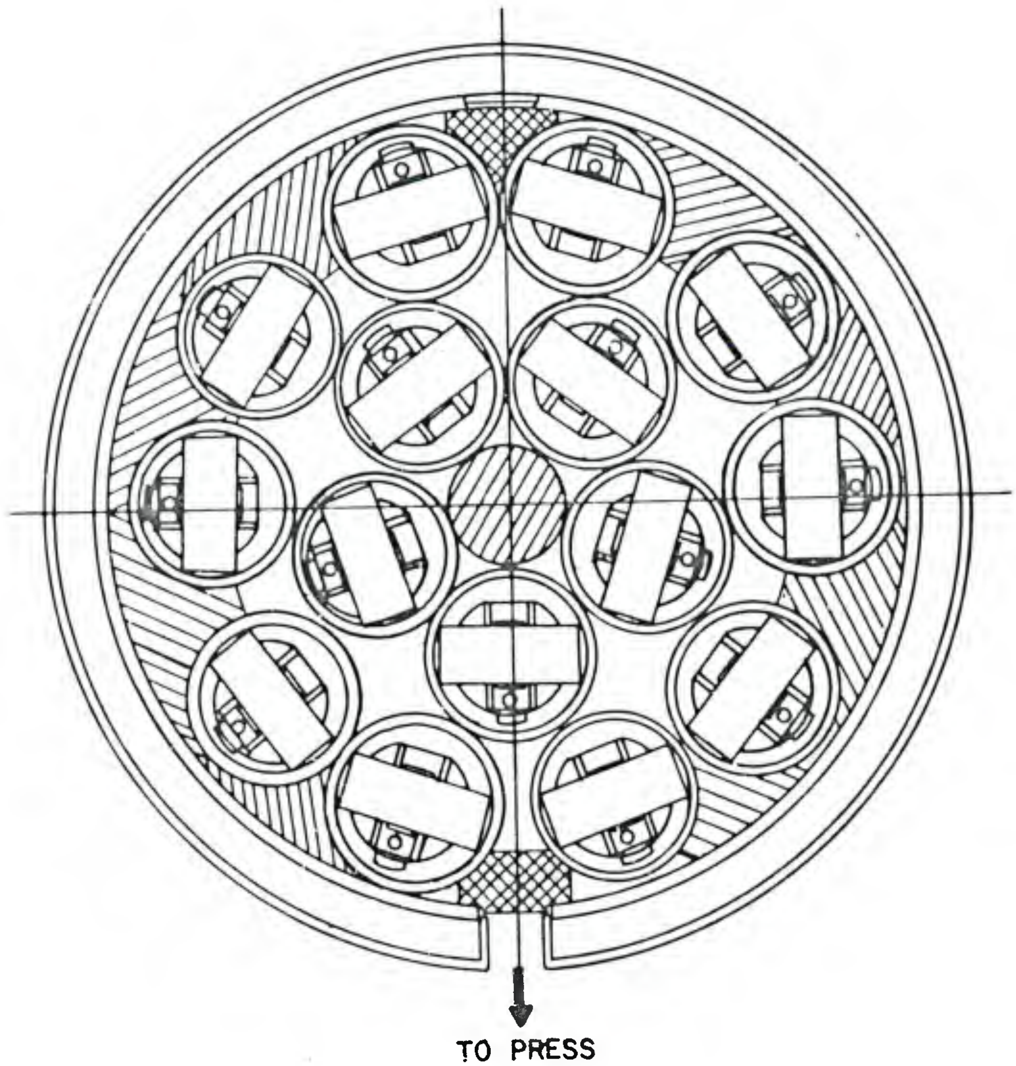

Figure 3. 8-Inch M[illegible]ring pack configuration

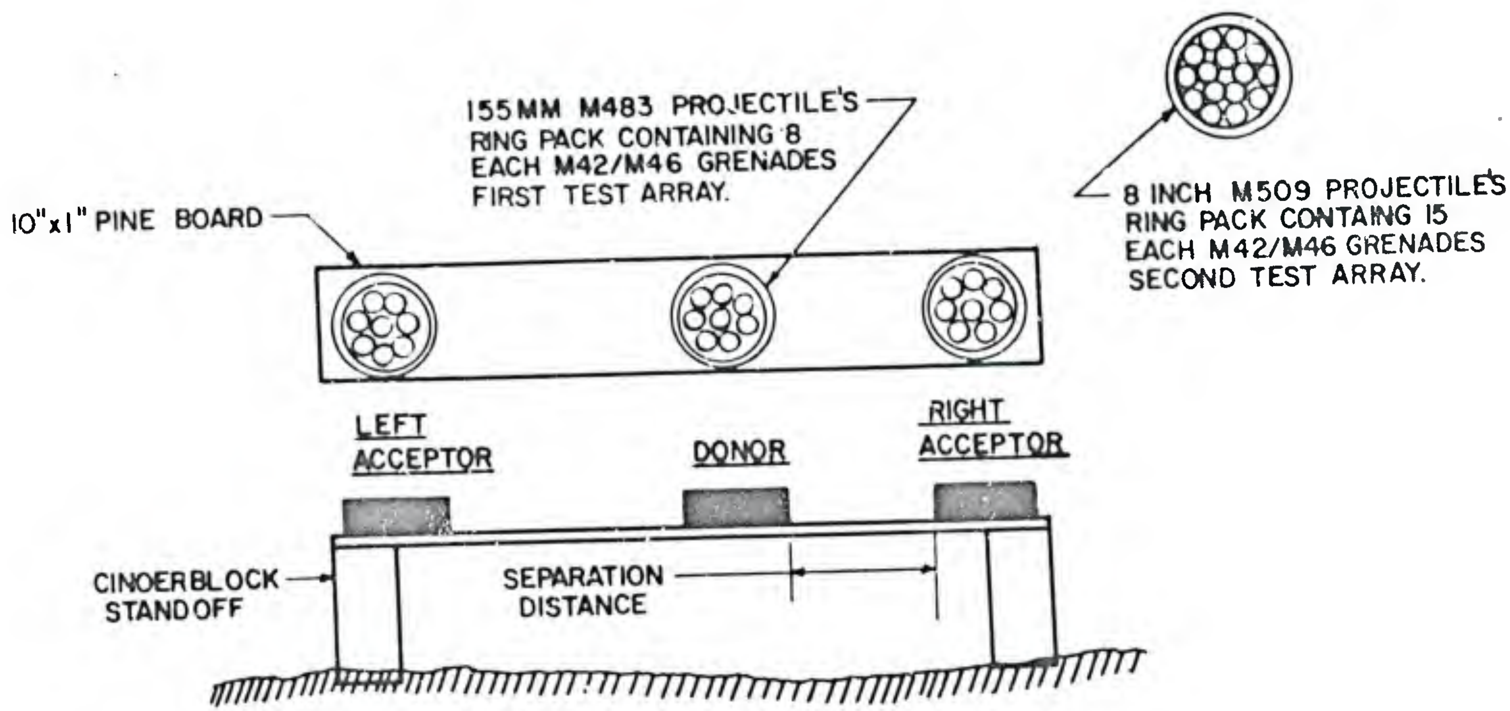

FIGURE 4. M42/M46 Grenade ring pack test

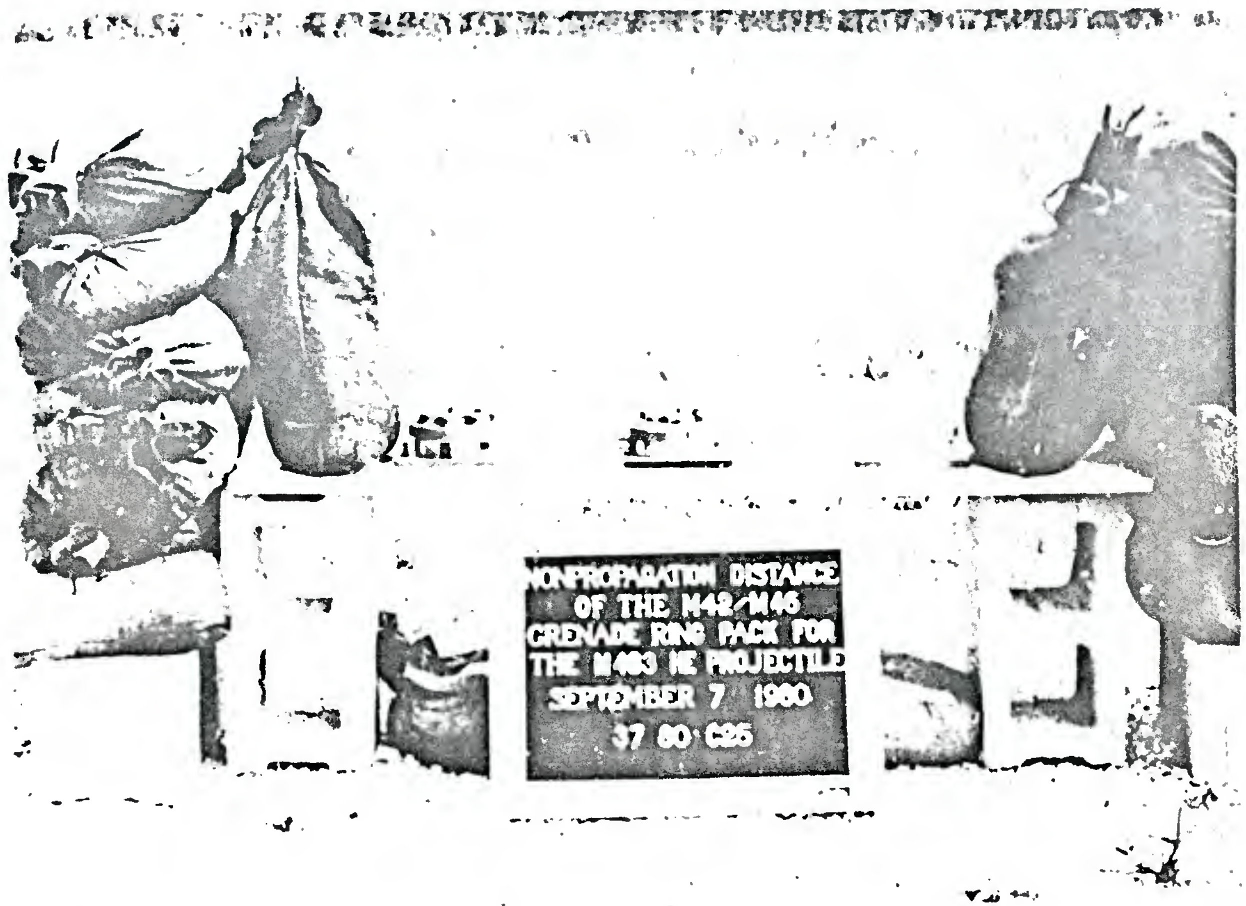

Figure 5. 8-Grenade ring pack; pre-test array

Figure 6. M509 - 15-Grenade ring pack; pre-test array

Figure 7. Single cluster trays; pre-test layout

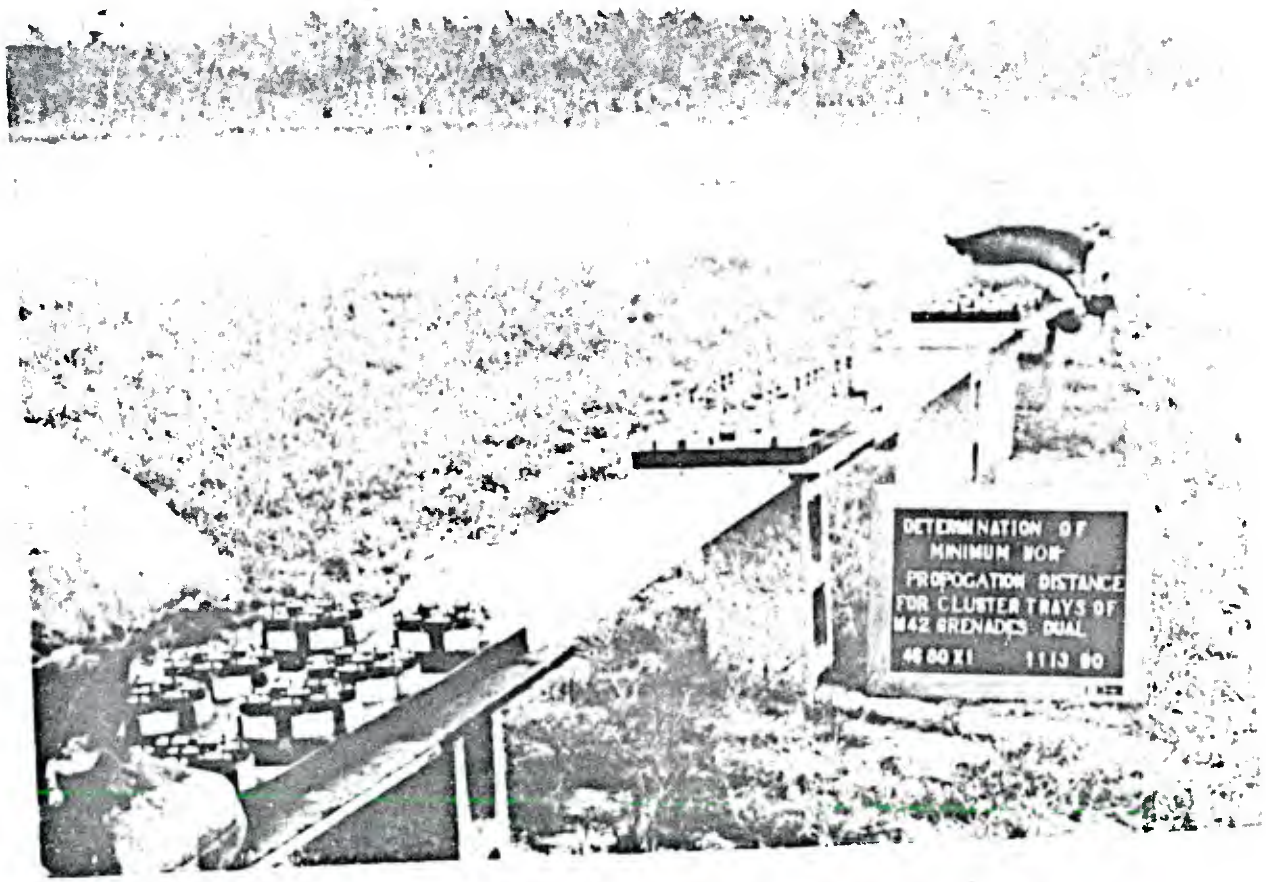

Figure 8. Dual cluster trays; pre-test layout

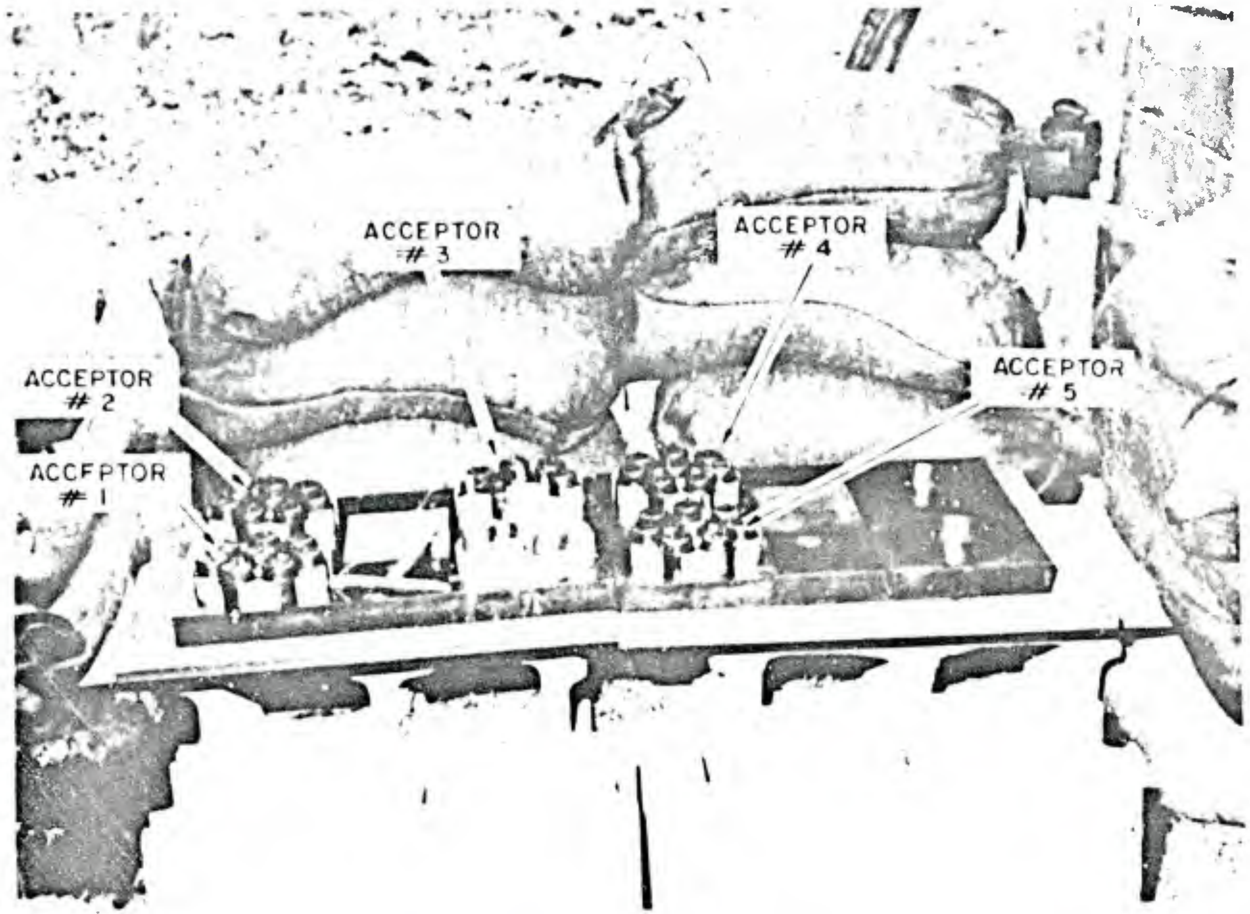

Figure 9. Cluster trays; final test layout

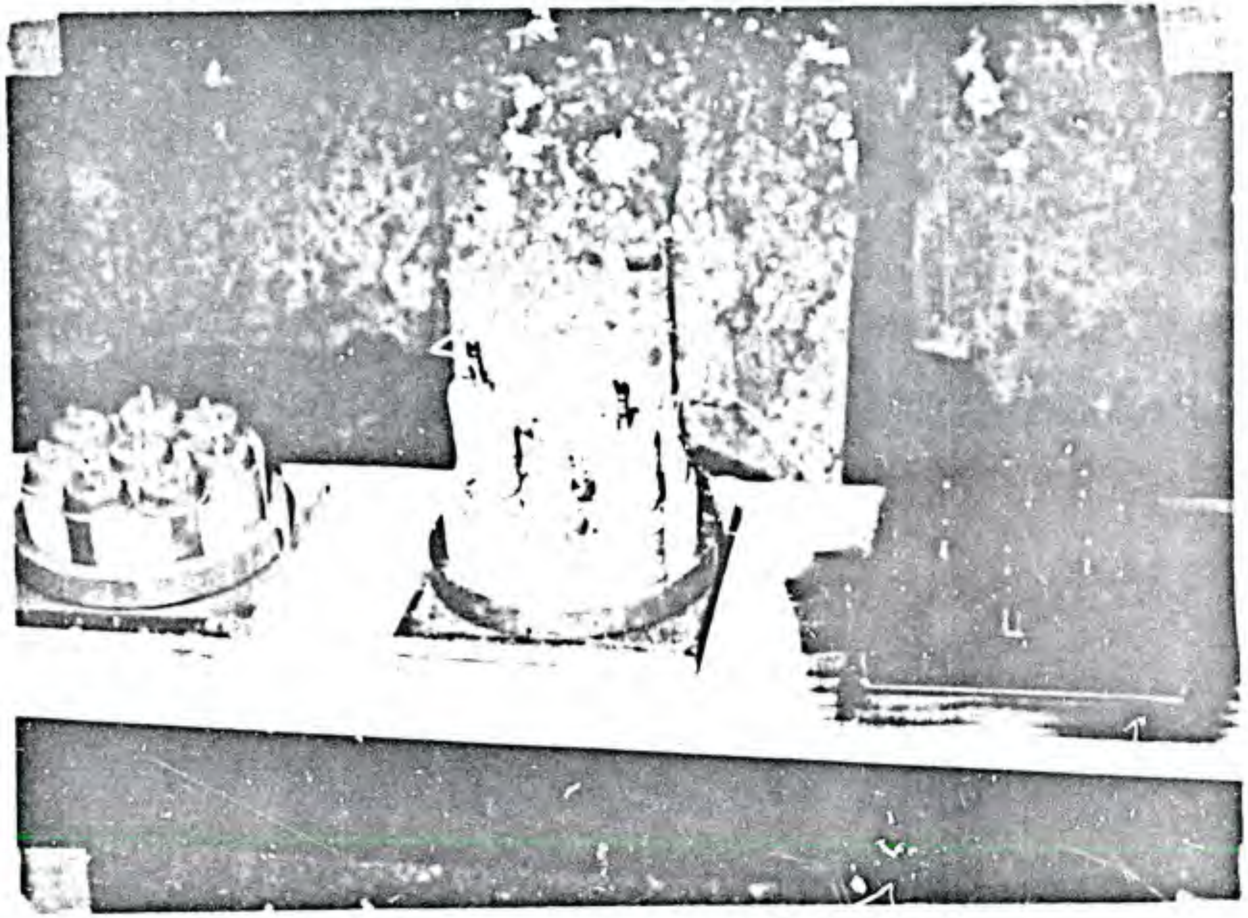

Figure 10. M483 ring pack primed

Figure 11. M509 ring pack primed

Figure 12. M483 ring pack witness plate

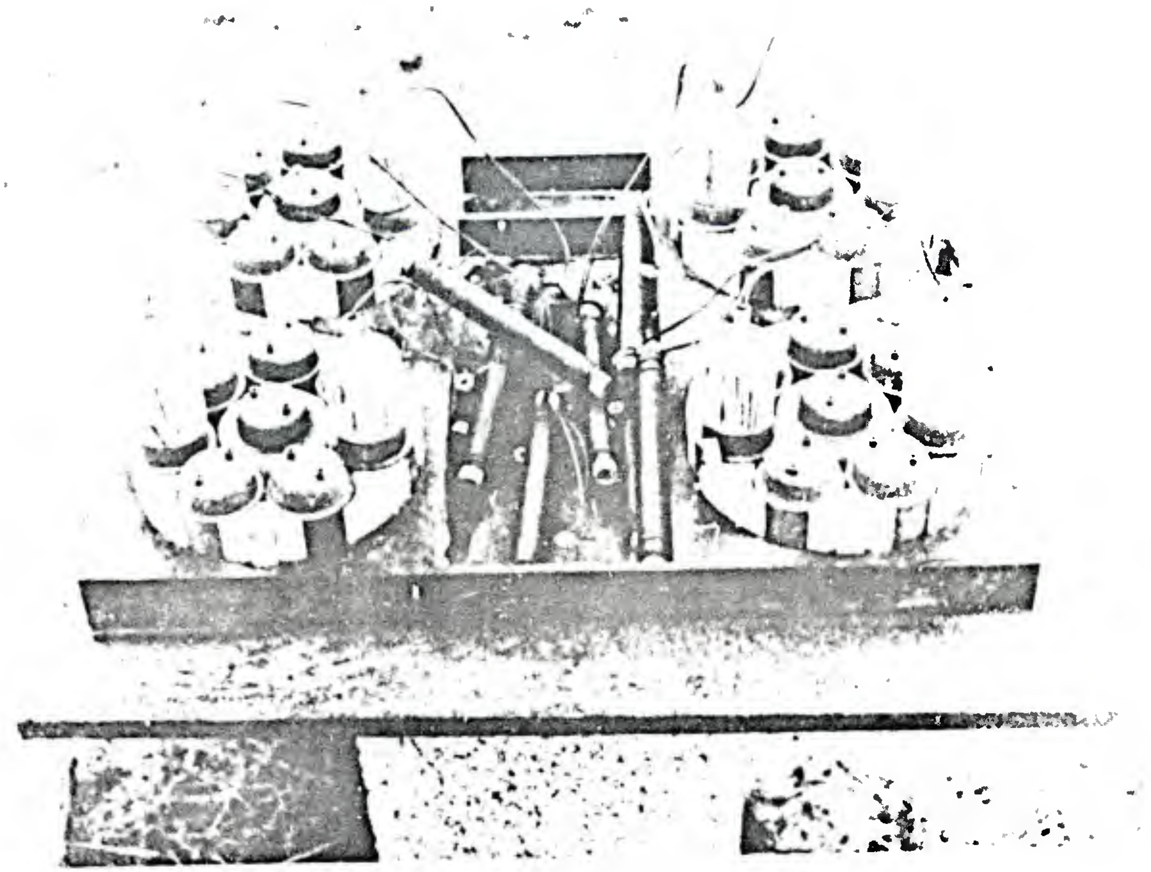

Figure 13. Single cluster tray primed

Figure 14. Dual cluster tray primed

Figure 15. Cluster tray donor witness plate

Figure 16. M483 ring pack; post-test - general view

Figure 17. M483 ring pack; post-test - propagation

Figure 18. M483 ring pack; post-test - close-up

Figure 19. M509 ring pack; post-test - general view

Figure 20. M509 ring pack; post-test - close-up

Figure 21. Cluster tray results

APPENDIX

STATISTICAL EVALUATION OF EXPLOSION PROPAGATION

Statistical Theory

The possibility of the occurrence of explosion propagation based upon a statistical analysis of the test results has been evaluated in the main body of the report. This appendix is devoted to the mathematical means by which the statistical analysis was performed.

The probability of the occurrence of an explosion propagation is dependent upon the degree of certainty or confidence level involved and has upper and lower limits. The lower limit for all confidence levels is zero; whereas the upper limit is a function of the number of observations or, in this particular case, the number of acceptor items tested. Since each observation is independent of the others and each observation has a constant probability of a reaction occurrence (explosion propagation), the number of reactions (x) in a given number of observations (n) will have a binomial distribution. Therefore, the estimate of the probability (p) of a reaction occurrence can be represented mathematically by

$$p = x/n \qquad (1)$$

and, therefore, the expected value of (x) is given by

$$E(x) = np \qquad (2)$$

Each confidence level will have a specific upper limit (p_2) depending upon the number of observations involved. The upper probability limit for a given confidence level α, when a reaction is not observed, is expressed as

$$(1 - p_2)^n = \varepsilon \qquad (3)$$

where $$\varepsilon = (1 - \alpha)/2 \text{ and } \alpha < 1.0 \qquad (4)$$

Use of equation 3 is illustrated in the following example:

Example

Determine the upper probability limit of the occurrence of an explosion propagation for a confidence level of 95% based upon 30 observations without a reaction occurrence.

Given

Number of Observations (n) = 30
Confidence Level (α) = 95%

Solution

1. Substitute the given value of (α) into equation 4 and solve for ε:

$\varepsilon = (1 - \alpha)/2 = (1 - 0.95)/2 = 0.025$

2. Substitute the given value of (n) and value of (α) into equation 3 and solve for p_2:

$$\varepsilon = 0.025 = (1 - p_2)^{30}$$

or

$$p_2 = 0.116(11.6\%)$$

<u>Conclusions</u>

For a 95% confidence level and 30 observations, the true value of the probability of explosion propagation will fall between zero and 0.116; or statistically, it can be interpreted that in 30 observations, a maximum of (0.116 x 30) = 3.48 observations could result in a reaction for a 95% confidence level.

Probability Table

Table A-1 shows the probability limits and the range of the expected value E(x) for different numbers of observations. Three confidence limits, 90, 95 and 99%, are used to derive the probabilities. The same values are plotted in Figure A-1.

Table A-1. Probabilities of propagation for various confidence limits

Number of observations	90%	C.L.	95%	C.L.	99%	C.L.
n	P2	E(x)	P2	E(x)	P2	E(x)
10	0.259	2.59	0.308	3.08	0.411	4.11
20	0.131	2.62	0.168	3.36	0.233	4.66
30	0.095	2.85	0.116	3.48	0.162	4.86
40	0.072	2.88	0.088	3.52	0.124	4.96
50	0.058	2.9	0.071	3.55	0.101	5.05
60	0.049	2.92	0.060	3.6	0.085	5.10
80	0.037	2.96	0.045	3.6	0.064	5.12
100	0.030	3.0	0.036	3.6	0.052	5.2
200	0.015	3.0	0.018	3.6	0.026	5.2
300	0.010	3.0	0.012	3.6	0.018	5.4
500	0.006	3.0	0.007	3.5	0.011	5.5

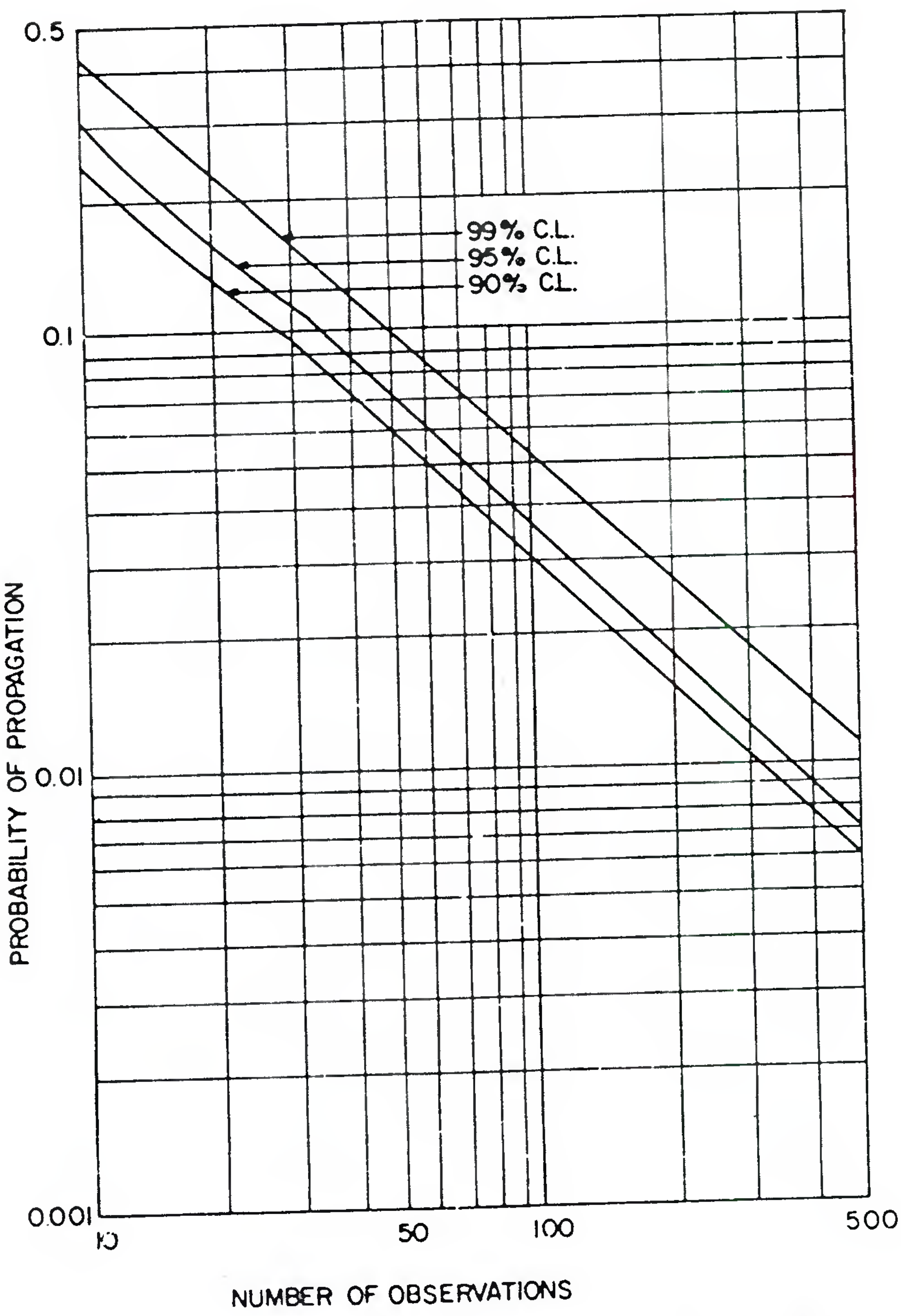

FIGURE A-1. Variations of propagation probability vs. number of observations as a function of confidence level.

DISTRIBUTION LIST

Commander
U.S. Army Armament Research and
Development Command
ATTN: DRDAR-CG
DRDAR-LC
DRDAR-LCM
DRDAR-LCM-S (12)
DRDAR-SF
DRDAR-TSS (5)
DRDAR-LCU-P
DRDAR-GCL
Dover, NJ 07801

Commander
U.S. Army Materiel Development and
Readiness Command
ATTN: DRCDE
DRCIS-E
DRCPA-E
DRCPP-I
DRCDL
DRCSG-S
5001 Eisenhower Avenue
Alexandria, VA 22333

Commander
USDRC Installations & Service Agency
ATTN: DRCIS-RI-IU
DRCIS-RI-IC
Rock Island, IL 61299

Commander
U.S. Army Armament Materiel
Readiness Command
ATTN: DRSAR-IR (2)
DRSAR-IRC
DRSAR-ISE (2)
DRSAR-IRC-E
DRSAR-PDM
DRSAR-LC (2)
DRSAR-ASF (2)
DRSAR-SF (3)
DRSAR-LEP-L
Rock Island, IL 61299

Chairman
Department of Defense Explosives
Safety Board (2)
Hoffman Building 1, Room 856C
2461 Eisenhower Avenue
Alexandria, VA 22331

Project Manager for Munitions Production
Base Modernization and Expansion
ATTN: DRCPLM-PBM-LA
DRCPM-PBM-T-SF
DRCPM-PBM-EP (2)
Dover, NJ 07801

Director
Ballistic Research Laboratory
U.S. Army Armament Research and
Development Command
ATTN: DRDAR-BLE, (C. Kingery) (2)
DRDAR-TBS-S
Aberdeen Proving Ground, MD 21010

Administrator
Defense Documentation Center
ATTN: Accessions Division
Cameron Station
Alexandria, VA 22314

Commander
U.S. Arm[illegible]struction Engineering
Researc[illegible]oratory
ATTN: CERL-ER
Champaign, IL 61820

Office, Chief of Engineers
ATTN: DAEN-MZA-E
Washington, D.C. 20314

U.S. Army Engineer District, Huntsville
ATTN: Construction Division-HAD-ED (2)
P.O. Box 1600, West Station
Huntsville, AL 35807

Director
U.S. Army Industrial Base
Engineering Activity
ATTN: DRXIB-MT (2)
Rock Island, IL 61299

Director
DARCOM Field Safety Activity
ATTN: DRXOS (5)
Charlestown, IN 47111

Commander
Crane Army Ammunition Plant
ATTN: SARCN
Crane, IN 47522

Commander
Hawthorne Army Ammunition Plant
ATTN: SARHW-SF
Hawthorne, NV 89415

Commander
Holston Army Ammunition Plant
ATTN: SARHO-E
Kingsport, TN 37662

Commander
Indiana Army Ammunition Plant
ATTN: SARIN-OR (2)
SARIN-SF
Charlestown, IN 47111

Commander
Iowa Army Ammunition Plant
ATTN: SARIO-S
Middletown, IA 52638

Commander
Kansas Army Ammunition Plant
ATTN: SARKA-CE
Parsons, KN 67537

Commander
Lone Star Army Ammunition Plant
ATTN: SARLS-IE
Texarkana, TX 57701

Commander
Longhorn Army Ammunition Plant
ATTN: SARLO-S
Marshall, TX 75607

Commander
McAlester Army Ammunition Plant
ATTN: SARVC-SF
McAlester, OK 74501

Commander
Milan Army Ammunition Plant
ATTN: SARMI-S
Milan, TN 38358

Commander
Radford Army Ammunition Plant
ATTN: SARRA-IE
Radford, VA 24141

Commander
Sunflower Army Ammunition Plant
ATTN: SARSU-S
Lawrence, KA 66044

Commander
Volunteer Army Ammunition Plant
ATTN: SARVO-S
Chattanooga, TN 37401

Commander
Pine Bluff Arsenal
ATTN: SARPB-SA
Pine Bluff, AR 71601

Commander
Rocky Mountain Arsenal
ATTN: SARRM-SAF
Denver, CO 80240

Director
U.S. Army Materiel Systems
Analysis Activity
ATTN: DRXSY-MP
Aberdeen Proving Ground, MD 21005

Commander/Director
Chemical Systems Laboratory
U.S. Army Armament Research and
Development Command
ATTN: DRDAR-CLB-PA
DRDAR-CLJ-L
APG, Edgewood Area, MD 21010

Chief
Benet Weapons Laboratory, LCWSL
Development Command
ATTN: DRDAR-LCB-TL
Watervliet, NY 12189

Commander
Badger Army Ammunition Plant
ATTN: SARBA
Baraboo, WI 53913